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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WASHINGTON, D.C. 20242

INTERAGENCY REPORT
NASA-124
September 1968

Mr. Robert Porter
Acting Program Chief,
Earth Resources Survey
Code SAR - NASA Headquarters
Washington, D.C. 20546

Dear Bob:

Transmitted herewith is one copy of:

INTERAGENCY REPORT NASA-124

PRELIMINARY EVALUATION OF INFRARED AND RADAR

IMAGERY, WASHINGTON AND OREGON COASTS*

by

Parke D. Snavely, Jr.**
and
Norman S. MacLeod**

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Sincerely yours,

William A. Fischer
Research Coordinator
EROS Program

*Work performed under NASA Contract No. W-12589 and Task No. 160-75-01-54-10
**U.S. Geological Survey, Menlo Park, California

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Prepared by the Geological Survey
for the National Aeronautics and
Space Administration (NASA)

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Norman S. MacLeod

U.S. Geological Survey
Menlo Park, California

PREFACE

This preliminary evaluation of the applications of infrared imagery to problems in marine geologic mapping (Task No. 160-75-01-54-10) is intended to serve as a Mission Analysis Report of NASA Convair 240, Mission 55 flown on August 16, 1967.

The images contained in this report are negative prints in which bright areas represent cool materials and black areas are relatively warm.

Contents

Illustrations

Introduction

This report summarizes the preliminary interpretation of infrared and radar imagery of parts of the Washington and Oregon coast. This coastal area is an ideal testing site for remote sensing techniques inasmuch as, in contrast to other imagery testing sites, it has a dense cover of vegetation and bedrock is poorly exposed. Thus it serves to define limitations of imagery in areas not ideally suited for geologic interpretation of conventional aerial photographs.

Much of the geology of this coastal area has been mapped as part of the U. S. Geological Survey's regional geologic mapping program. More recently, detailed investigations of the geology of the Oregon and Washington coast have been undertaken as part of the study of the stratigraphy, structure, economic potential and origin of the continental shelf extending from the continental margin to the Coast Ranges. Because much of the existing mapping of the coastal belt is reconnaissance, more detailed mapping of selected areas has been required for the interpretation of some features shown by the imagery. Field studies of most of these features will be completed by September, 1968, and a detailed report of the infrared and radar imagery will be prepared.

Infrared [illegible]

Infrared imagery of the [illegible] and northern [illegible] coast was acquired by a N.A.S.A. Reconofax IV I.R. Imager sensitive to the 8 to 14 micron band. The images were obtained on August [illegible], 1967 between 1743 and 1825 hours from an altitude of 15,000 feet. Scale on the 70 mm film on which the imagery is recorded varies somewhat but in most areas is about 1:70,000; scale parallel to the flight path differs from that normal to the path resulting in slight distortion. Selected parts of the original imagery were enlarged 3.5 times for detailed analyses.

The coastal area shown in the infrared imagery is characterized by high annual rainfall and dense vegetation. Several rivers whose headwaters are in the Olympic Mountains discharge into the sea along the northern Washington coast; among the larger of these are the Soleduck, Hoh, Queets, and Quinault Rivers. The Chehalis, Willapa and the Columbia Rivers discharge to the sea in the southern coast through Grays Harbor, Willapa Bay and the Columbia estuary.

Lower Eocene to Pliocene sedimentary and volcanic rocks crop out on wave-cut platforms, sea cliffs, and rugged headlands between Grays Harbor and Cape Flattery along the Washington coast. Pleistocene glacial debris blankets most of the inland area and locally extends beyond the coast line. South of Grays Harbor to the Columbia River the coastal area is characterized by broad beaches, and spits that are mantled by dune deposits; Tertiary bedrock is exposed only in a few places.

[illegible] in the [illegible] with which to unravel the complex [illegible] provide data on nearshore marine processes. [illegible] the imagery indicate that it is of [illegible] value in respect to [illegible] bedrock geologic features. Variations in rock lithology could not [illegible] discerned on the imagery nor could most structural elements such as large faults. A slight linear thermal anomaly is shown near Point Grenville over the trace of a large north trending fault. It is very faint and would probably not have been noted had the presence of the fault not been known. It appears as a narrow band of slightly higher relative temperature extending from a raised terrace onto the adjacent beach, and probably is produced by discharge of relatively warm spring water along the fault trace.

Color aerial photographs of the coastal area, on the other hand, show geologic features such as bedding, lithologic contacts, and faults very clearly. Enhanced, false-color composites of an infrared image of a wide wave-cut platform on the coast near Ozette Island are now being prepared. These may enhance lithology-produced thermal variations not otherwise visible in the infrared imagery. An enhanced, false color composite of a color aerial photograph of this same area is also being prepared in order to provide an additional basis for comparison of infrared imagery and color aerial photographs.

Even though the infrared imagery has not been particularly useful in respect to showing bedrock features, it does show remarkable thermal variations in sea water adjacent to the coast. These are significant with respect to [illegible] their relationship to present day [illegible].

Banded aprons of warm river water are [illegible] on the [illegible] imagery off the mouths of several rivers along the [illegible] coast. These are best developed at the mouths of the Quinault, Queets, and Hoh Rivers, shown in Figures 1, 2 and 3. The aprons of warm water extend at least 7000 feet offshore, beyond the limit of available imagery, and are 5000 to 15,000 feet wide in the north-south direction. They are crudely semicircular in shape and most are deflected southward with respect to the river mouths due to longshore currents and (or) prevailing winds. They extend seaward from an area beyond the low tide line and are connected to the river mouths by a narrow belt of warm river water.

The internal structure of the aprons is complex. For instance, the apron off the Quinault River is composed of at least two impinging plumes, one of which appears older. The axis of the older Quinault plume, and also that of the much fainter of two plumes developed off the Queets River, is parallel to but located about 2500 feet from that of the younger plume. The individual plumes contain more than five pronounced concentric thermal bands. The outer limit of each band is sharp and contains relatively warm water; the water temperature within individual bands decreases [illegible]ally landward. Small faint concentric bands occur within and parallel to borders of the larger bands.

These concentrically banded thermal plumes most likely formed as a result of pulsing discharge of fresh river water in dynamic response to the tide. [illegible] mouth of any of the [illegible] rivers, [illegible] like a submerged weir. [illegible] would increase on a falling tide and would [illegible] before, or concurrently with, the [illegible] of the tide cycle. Discharge would diminish on a rising tide and would [illegible] a minimum just before, or with, high tide. At the time of [illegible] imagery in mid-August, streamflow would have been near its yearly minimum and freshwater discharge through the longshore breach at high tide could be small or nonexistent. The imagery was taken during a rising tide at the time when fresh-water discharge would tend to be impounded by the rising salt water offshore, as though by a rising dam. Such behavior would be compatible with the distinctly sharp edges of the fresh-water plume as it first diverges, close inshore. On a falling tide, the impounded fresh-water would tend to be freed so that a "feathered" edge to the thermal bands would be expected. Fresh river water would tend to float above ocean water, both offshore and in the estuarine reach of the river, due to density difference accentuated by thermal and dissolved-solid differences. Except in the surf zone, movement of water is much closer to laminar than turbulent, so that mixing and diffusion are relatively slow.

Several infrared images made at about 2 hour intervals between high tides would provide the data needed to interpret plume origin.

[illegible] a point within the plume [illegible] These would provide [illegible] of [illegible] and [illegible] or prevailing winds. They may also provide [illegible] of suspended sediment within [illegible] by the plumes. Such data would be very useful for the interpretation of sediment deposition off river mouths.

Several other water features are shown by the infrared imagery. A wave agitated belt 500 to 1500 feet wide immediately adjacent to the coast where no wave-cut platforms are present is shown by a zone of complex thermal patterns. The width of this belt provides a measure of the dispersal of beach sediment by wave action. Discharge of warm water from probable fresh water springs near the edge of wave-cut platforms is shown by the infrared images between Sand Point and Cape Alava, Ozette quadrangle, and in several other places on the Washington coast (Figure 4). Cuspate thermal patterns around reefs, small islands, and headlands show the direction of net transport of surface water as a result either of longshore currents or prevailing winds. Thermal eddies in surface waters of small coastal embayments are shown in the imagery and result from topographic interference with surface water transport.

Large-scale rhomboid ripples show in the infrared imagery in Willapa Bay (Figure 5). The ripples have wave lengths of about 200 feet and have superimposed sand waves which trend normal to the rhomboid ripples. Both wave forms are probably the result of rapid [illegible] flow on tidal flats during outgoing tide. After these features are investigated in the field they will be reported upon more fully.

Radar Imagery

Preliminary interpretation of radar imagery of a 10 miles wide strip of the Oregon Coast extending from the California border to the Columbia River is reported in Snavely and Wagner (1966). Since submittal of that report, field evaluations of the radar imagery have continued but, because of the large area involved, are not yet complete. Principal conclusions presented in the technical letter are: (1) radar imagery provides a very clear rendition of the topography and in essence "defoliates" the thick cover of vegetation; (2) rocks of high density and surface roughness underlie areas depicted on the imagery with light tones, and rocks with low density and (or) high water content underlie areas which appear dark on the imagery; and (3) fault traces can be discerned on the imagery by juxtaposition of areas with different tonal rendition and by associated linear topographic features.

Reconnaissance field mapping during the last year has shown that several anomalous linear features on the imagery are expressions of previously unrecognized faults. The largest of these faults trends northeast from near the mouth of Drift Creek (south of Lincoln City) for a distance of at least 10 miles and is expressed on the radar imagery as an aligned series of hills and streams. Field investigations have shown that several other similar linear features on the radar imagery, however, result from topographic expression of particularly resistant beds. Therefore, careful field investigations are a prerequisite to geologic evaluation of the radar imagery.

Additional field work including detailed ground and aeromagnetic surveys are planned during the summer of 1968 on an arcuate volcanic structure, described in Snavely and Wagner (1966) which occurs 10 miles south of Astoria. It is anticipated that the investigations of this structure and field studies of other structural elements shown on the radar imagery will be completed during the summer of 1968 and a comprehensive report on the geologic evaluation of the radar imagery will then be issued.

Reference Cited:

Snavely, P. D., Jr., and Wagner, H. C., 1966, Geological evaluation of AN/APQ-97 radar imagery, Oregon coast: U. S. Geol. Survey Tech. Letter NASA-16, 7 p.

Figure 1. Enlarged infrared (8 to 14 μ) image of mouth of Quinault River, Taholah, Washington. Two plumes of relatively warm river water spread seaward from near river mouth. Note the well defined thermal bands with sharp outer margins and gradual inward decrease in relative temperature. Sand bar is present on south side of river mouth. Rectangular light areas north of river are logging tracts. Distance from bridge to river mouth is about 3600 feet.

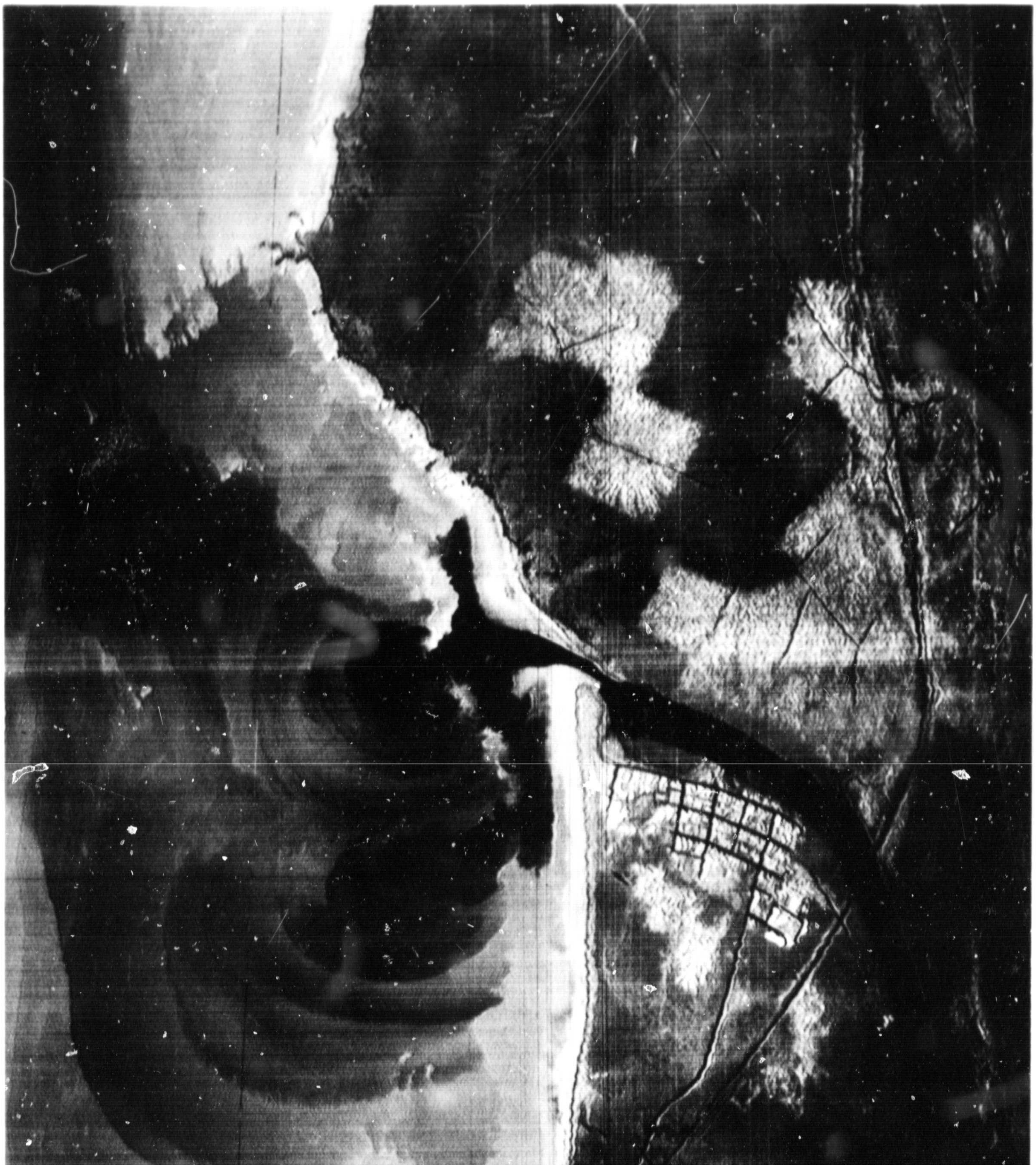

Figure 1.

Figure 2. Infrared (8 - 14 μ) image of mouth of Queets River. Thermally banded plume extends southward from river mouth. Faint older plume is visible immediately to left, and concentric to, river mouth. Marshy area (light) on southwest extension river below bridge probable is former river channel. Distance from bridge to river mouth is 5,600 feet.

Figure 2.

Figure 3. Infrared (8 to 14 μ) image of mouth of Hoh River showing banded thermal plume. Banded pattern is destroyed adjacent to coast by wave-agitation. Distance from river mouth to right hand margin of image is 3,000 feet.

Figure 3.

"REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR"

[illegible] 4. Infrared image of [illegible] near Onoto Island, [illegible] platform is subject to much [illegible] appears to show fresh water springs ([illegible] warm areas) that discharge from the [illegible]. [illegible] and fracture systems along the coastline [illegible] evident in this area and are enhanced by infrared images.


N
SUBMARINE
WAVE CUT PLATFORM
FAULT
ASA Mission 55
8/16/67
Site 7 04:20 AM Pdt
AREA EAST OF
OZETTE ISLAND, WASH.

Figure 4.

[illegible] perpendicular to the [illegible]. [illegible] are probably the [illegible]


N
RIPPLES IN TIDAL FLATS
NASA MISSION 55
8/16/67
Site 7 Predawn
MOUTH OF
WILLAPA BAY,
WASHINGTON

Figure 5.